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COMMONIST CHINA'S PROGRESS IN INORGANIC, ORGANIC, AND PHYSICAL  
CHEMISTRY IN RECENT DECADE

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### FOREWORD

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COMMUNIST CHINA'S PROGRESS IN INORGANIC, ORGANIC, AND PHYSICAL  
CHEMISTRY IN RECENT DECADE

[The information in this report was taken from the Hua-hsueh  
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## I. CHINA'S PROGRESS IN INORGANIC CHEMISTRY IN RECENT DECADE

Pages 3-5

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China has a glorious history and tradition in the study of inorganic matter. Ancient alchemists, such as Wei Pai-yang (Eastern Han) of the 2nd century A.D. and Ko Hung (Eastern Tsin) of the 4th century A.D. prepared many inorganic substances and observed numerous inorganic chemical reactions. Ancient Chinese inorganic technology such as China (3rd century A.D. The Three Kingdoms) and black powder (7th century A.D. T'ang Dynasty) manufacturing are well known to the whole world. The modern western chemistry, which started in the last part of the 18th century, was initiated by the discovery of gaseous elements and the establishment of the oxidation theory. The new modern chemistry was introduced to China in the middle of the 19th century, however, under a semi-feudal and semi-colonial situation, development was hindered. Following the revival of national technology in World War I, inorganic chemistry, like other branches of chemistry, made some progress. One of the noted accomplishments was the new method for the preparation of alkalis invented by Hou Te-pang.

Throughout the world, this ancient inorganic chemistry again showed its youthful vigor in the fourth decade of this 20th century. It was the urgent demand for inorganic materials by atomic energy, electronics, jet technology, etc., which promoted the speedy progress of inorganic chemistry. However, the situation in China was different. The reactionary Kuomintang government paid no attention to scientific development, not even to such tremendous progress as was taking place in inorganic chemistry. It was not until the Communist Party took over a decade ago that inorganic chemistry as well as other branches of science had proper development.

The following are the major factors which promote the progress of China's inorganic chemistry:

### 1. The Utilization of Mineral Resources, Especially Rare Elements.

Prior to the Liberation, the only rare element which was given enough attention was wolfram; however, no finishing process was available in China. The situation has been drastically changed since the Liberation. The survey report made by the Department of Geology based on their extensive investigation revealed that rare element resources are extraordinarily rich in our country. Other industrial by-products: furnace residue, smelter ash, anode residue, ammonia aqua from coke process, etc., are all excellent sources for scattered rare elements.

During the past decade, many rare elements have been obtained through refining, and most of them have had important effects in the socialist construction program of China. The expansion of the national economy greatly pushes forward the development of rare element chemistry, but first of all the refining process for rare elements should be improved, or maybe a new process is needed,

## 2. Advanced Technology.

Peaceful utilisation of atomic energy, electronic technology, jet techniques and many others require a special kind of inorganic materials which include radioactive elements, stable isotopes, super-pure elements, rare elements, high energy fuel, high temperature materials, etc.; these demands strongly push forward the progress of inorganic chemistry. The situation in recent years is particularly outstanding. Many remarkable accomplishments were achieved during the initial stage of the 1958 scientific research great forward leap; and many special experimental techniques and new preparation methods have also successively been developed in the production process. The conclusion is that we have had a good start in this field.

## 3. The Great Forward Leap of Agriculture and Industry.

Through the over-fulfillment of the three-year recovery plan and the First Five-Year Plan (1953-1957) since the Liberation, the productivity of China's agriculture and industry is on a solid foundation. The three year advance fulfillment of the giant indexes of the Second Five-Year Plan (1958-1962) will further demonstrate the tremendous development of this productivity. We believe that the origin and the developing process of science are basically determined by production; therefore, the forward leap of agriculture and industry will definitely stimulate the development of chemistry, of which inorganic chemistry is a branch. Inorganic chemistry is not only directly related to the basic chemical industry, but acid, alkalies, salt and chemical fertilisers also have a connection with black metals, colored metals, construction materials, etc. Chemical fertilisers and chemical insecticides support agricultural industry. Agriculture and industry also constantly request more from inorganic chemistry; therefore, regardless of whether the demand is qualitative or quantitative, or even if it involves the preparation of new items, all will stimulate research in inorganic chemistry.

## 4. Scientific Planning and Soviet Assistance.

In 1956, a 12-year (1956-1967) scientific technology development long-range plan was prepared; it indicates the five directions that our inorganic chemistry will follow in the future: (1) rare element chemistry,

(2) chemistry of complex products, (3) inorganic synthesis, (4) physical chemistry analysis, and (5) isotope chemistry. The explanation attached to each item gives good reference to our research workers.

The development of China's science and technology cannot be separated from the brotherly assistance given by the Soviet Union. In 1955 and 1956, Soviet academicians Ia-na-na-yeh-fu and Fu-er-fu-ko-wei-chi visited China successively, and offered valuable information on the development of inorganic chemistry. In 1958, China and the Soviet Union signed an agreement to carry out jointly significant scientific research, and the Soviet Union will also help China to carry out such research projects. Some 122 items were decided in the agreement for future cooperation. Inorganic chemistry research is definitely promoted by this agreement. Besides, we are getting assistance from other brotherly countries.

During the past decade, many satisfactory accomplishments have been secured in the field of inorganic chemistry; although these accomplishments are initial, nevertheless the foundation of future development has been established.

#### Rare element chemistry

The major work in this field is the refining of mineral rocks and other resources. We have succeeded in the study of the processes for light rare elements, rare earth elements, hard-melting rare elements, disperse elements, and elements of the platinum family. More work has been done on wolfram because it is specially rich in our country. We have tried many different processes to obtain pure tungstic acid by decomposition of black wolfram mineral rock, but the best method found so far is to convert ammonium tungstate crystal into sodium tungstate solution, precipitate as tungstic acid which will again be converted to ammonium tungstate crystal, and finally the crystal is decomposed by hydrochloric acid. The tungstic acid thus obtained is 99.99% pure  $WO_3$ . The conditions of precipitation have also been studied; sodium tungstate solution is completely converted into tungstic acid ions which, after boiled and staled, is added to concentrated hydrochloric acid. The final result is tungstic acid in yellow powder form and is easy to wash and filter out. The yellow powder contains only 0.005% iron. The destruction of the tungstic acid ions has to depend on hydrochloric acid because the decomposition process requires the action of complex compound of chlorine. We also studied the preparation of phospho-tungstic acid and polyvanadium acid.

Spectrum, polarisation and colorimetric methods have all been used in the analytical chemistry study of rare elements. One of the examples is the use of emissive spectrum to determine the micro quantities of

lanthanum, praseodymium, and neodymium in cerium; and the systematic quantitative analysis of tungsten and molybdenum. We also improved the methods used in the total analysis of rare earth contents in ferric rocks and tin rocks which are rich in rare metals.

### Chemistry of complex compounds

Most of the work in this field is to study complex compounds in solution, all physical methods are used. The method to measure the various stability constants of complex compounds by the use of polarographic half-wave potential is improved. More accurate stability constants for various sulfo-cyanate salts are secured. The polarographic method proves that there are new complex ions of thallous sulfo-cyanate with 2, 3 and 4 coordination numbers. The use of the ph method has shown that complex reactions happen between alkali metal ions and mono-basic, binary and replaced carboxylic acid, which indicates that the ionisation constants measured by previous chemists with sodium hydroxide or potassium were too high. We also used  $N(CH_3)_4OH$  to measure again the ionisation constants for succinic acid, tartaric acid, and ferrocyanide acid as well as their association constants with more than ten kinds of metal ions. We also studied the ionisation constants for N-phenylglycine acid and N- $\alpha$ -naphthylamine acetic acid in ethyl alcohol-water solution and their stability constants with copper and nickel compounds. In addition, we used the solubility method to study complex compounds in solution; the new general method was demonstrated with lead iodide complex compounds.

Our optical study of complex ions was based on the theory of continuous variation of concentration and selected different optical activity, optical density, and refractive index giving additive and harmonious physical properties to study the complex reaction of tartaric acid and ions of copper, iron and cobalt. When we studied the complex reactions of iron and pyrocatechol with the photo-absorption method, two new complex ions were learned; one is a 2:1 (Fe: phenol) green-yellow colored positive ion at pH=2, another one is a 1:3 blue positive ion at pH=5.9. The use of optical density and electrical transferring method to study the complex formation reaction between sulfocyanide radical and five-valence molybdenum in water-acetone solution has proved the existence of two new positive ions, one is 1:1 (molybdenum: sulfocyanide radical) and the other one is 1:4.

One theory concerning the equilibrium of complex ions in solution is as follows: we may consider that the complex action in solution is similar to absorption action: metal ion is equivalent to the absorption center of an absorption agent and the coordinating compound is equivalent to solute; therefore, we can use the Fu-long-Yieh-che equation to express



the average complex numbers and their logarithms. As a result we may express such properties as polarographical half-wave potential, oxidation-reduction potential, extraction percentage, solubility, etc., which vary with the concentration of the coordinating compound by the Fu-long-lich-she equation, as the expression for various equilibrium constants; one-is-supplementary to the other.

### Inorganic synthesis

A major project is to obtain high purity materials. We have prepared super pure germanium and silicon which are qualified semiconductor materials; we have also controlled the method of belt smelting and reduction of chlorides with hydrogen. The former is used to prepare elastic high-purity antimony. Both the high vacuum method and the extraction method are being used to produce high-purity materials. An improved S-pi-tin ion-exchange method has been used to separate 15 different rare earth elements to their spectrum pure condition. Many synthetic projects are designed to support the preparation of inorganic materials. The production of chemical testing materials has been increased abruptly, many new items include rare element test agents and spectrum test agents. A new regulation governing test materials is being worked out.

We are successful in the identification of chemical units. The so-called Benson's antimony pentasulfide has been proved as the compound system of antimony sulfide and  $\Delta$  sulfur, instead of a chemical unit according to thermo-differential analysis and the evaluation of sulfur extracted out at  $160^\circ$ .

### Physical chemistry analysis

Work has been developed under the influence of Russia's Ku-er-na-kou-fu theory. In an aqueous salt system, fused salt system and metal system, work has been carried out; in the meantime, some equipment, such as a thermo-differential analysis set-up, heat balance, phase microscope, polarized microscope, X-ray diffraction unit, etc., have been set up.

In the study of sea water, water containing potassium from Na, K, Mg Cl, and  $SO_4$  type salt lakes, and from Na Cl,  $SO_4$ ,  $CO_3$ , and  $HCO_3$  type alkali lakes, we have succeeded in extracting potassium salt, preparing potassium fertilizers and extracting alkalies in industry. Studying the NaF-AlF<sub>3</sub> system, we have fixed the proper conditions for the electrolyte in aluminum refining process. About the silicate system, the phase problem for  $Na_2O-SiO_2-SiCl_4$  was studied, the speed-temperature-time relationship of the viscosity method may be applied

in the production process of rich quartz glass. In connection with the special features of China's iron ores, ore residues with fluorine content, high titanium content and high magnesium content have been studied. We used a physical chemistry analytical method in connection with physical chemistry and mechanical properties to study the Fe-W-Si system, boron steel system, Cr-Ni-Mo steel system and Cr-Ni-Mo-Ti steel system. The results have significant practical meaning in production. Furthermore, we have studied systems with rare elements.

A number of tri-element system with common positive ions, including  $\text{KCl-K}_2\text{SO}_4\text{-H}_2\text{O}$  and  $\text{KHCO}_3\text{-K}_2\text{SO}_4\text{-H}_2\text{O}$  have been probed, the work includes the study of their solubility curves, the mutual effects on the degree of solubility by ion pairs, and some theories on concentrated solution. We also studied the Al-Cu-Ni and Al-Co-Ni alloy systems with the X-ray diffraction method; from the existence and transformation of the cavity, we probed the structure of the individual phase and discovered the super structure. Also, in the Al-Ni and Al-Co-Ni systems, we found the structure relationship between metal compounds and their family products, and identified the corresponding transition phase. From Ag-Au-Zn system's slow-cooling phase diagram, we noticed some phase change structure. Other theoretical study includes the kinetics of alloy ordered inversion thermodynamic study of iron-carbon phase diagram, and the statistical theory of the binary solid solution.

### Isotope chemistry

In the electrolytic separation of hydrogen isotopes, we have studied the effect of high current density on the separation coefficient. Using platinum wire anode, dilute sodium hydroxide electrolyte, 1-13 amperes/cm<sup>2</sup> current density, and room temperature, the separation coefficient thus obtained is around 7, which agrees with the "proton transformation" process in the hydrogen super potential theory. This result indicates the possibility that a high current density may be used to strengthen electrolytic process. Equipment with index atomic compounds improved the yield rate of  $\text{H}_2^{18}$  and  $\text{H}_2^{17}$ .

The thermo-expansion effect of heavy water was carefully investigated. The solubility of potassium dichromate and cadmium iodide in the mixture of ordinary and heavy water at 25° shows that the effect produced by the second D atom when it is substituted into water molecule is only about 60% of the effect produced by the first D atom. So far as the theory which states that the catalytic action of the deuterium ion is stronger than hydrogen ion is concerned, the study of the Lang-tao-er-te reaction in heavy water at room temperature has proved it true; in the meantime, we studied the techniques of measuring the reaction rates of color appearing and color fading in one milliliter solution.

The use of a radioactive isotope as an index atom to seek understanding about the valence and bond characteristics and the theory of exchange reaction of metallic organic compounds was probed. We also studied the isotope exchange of antimony-m-mesitylene and its chloride in ethyl alcohol solution. The exchange activity measured was 14 kcal/gram-molecule. Similar compounds including antimony-p-mesitylene and antimony triphenol have also been studied.

In the analysis of water isotopes, the form of the Cartesian diver was studied; the most suitable form is the shuttle diver which has the maximum range for the linear relationship between the up-and-down speed of the diver and the temperature difference of the "floating temperature." The range is usually around  $\pm 0.6^\circ$ . So far as the drop method is concerned, the mixture made of  $\alpha$ -chloronaphthalenes and diesel oil distillation fraction with corresponding boiling point is suitable to measure heavy water of all concentrations with an accuracy of 0.02-0.03%. In the process of total analysis of very diluted heavy water, we used the balance method by passing carbon dioxide through sodium bicarbonate solution to remove excess O-18 and employed the diver method to take measurements. Among the more than 50 samples from water sources all over the country, this method has been used to determine the contents of semi-heavy water and hydrogen peroxide in high-density samples.

Looking back at the development of our inorganic chemistry in the past decade, we believe that today's achievement from a blank past is mainly due to the precise leadership of the Party. Prior to the Liberation, there was basically no inorganic course offered in advanced schools. But now inorganic chemistry has not only become the number one basic course in chemistry departments of general universities and in the chemical engineering department of chemical engineering colleges, but many specialized courses, such as rare element chemistry, complex ion chemistry, and inorganic synthesis have been set-up to train specialized workers. And many advanced colleges are carrying out inorganic studies important to the development of our national economy. Large inorganic research projects are being performed in the research institutes of the Academy of Science and the Ministry of Chemical Industry. Our equipment and our strength are growing gradually; we should say that our achievements are great. However, on the other hand, the accomplishments we have made so far are too small to satisfy the demand requested by the magnificent socialist construction program and the leap forward guided by the light of the general line. Therefore, more work should be carried out by our inorganic workers; the following are our opinions. We welcome discussion.

1. To further associate theory with practical work is the super-highway toward the development of any science. The speedy increase of our national economy is the motivating force which propels the progress

of science. In the field of inorganic chemistry, many problems initiated by the peaceful uses of atomic energy, electronic techniques, jet techniques, metal alloys, basic chemical industry, rare elements, and rich chemical resources are waiting for solutions. Therefore, our inorganic chemistry workers must bear in mind the development of China's productive power to struggle to complete important scientific tasks which are vital to our national economy. In the meantime, we should emphasize theoretical study which is directly related to practical situations. Only through the proper development of theory can practical production be given powerful guidance.

2. The development of inorganic chemistry should be a balanced one. Because of urgency in some production projects, progress in the past was unbalanced. For instance, emphasis was given to extraction of rare elements instead of on the basic chemistry study of such elements; no work was done on the synthesis of complex compounds, most of the work in the past was concentrated on the study of complex compounds in solution. In the field of inorganic synthesis, emphasis was on preparation instead of the study of the properties, structure, and reaction theory; the physical chemistry analytical work should be broader and deeper, this is also true with the study of isotopes, more theoretical work should be performed. In future development, a balanced over-all situation should be emphasized.

3. In inorganic research, close coordination among various branches and complex chemistry and physical chemistry analysis should keep close contact with separation, extraction and synthesis of rare elements. Inorganic synthesis should closely maintain contact with rare elements and rich chemical resource utilisation should be maintained. Especially important is that the study of inorganic chemistry requires the modern equipment and methods from physical chemistry and physics. We should widely establish high temperature, low temperature, high pressure, high vacuum, thermal spectrum, thermal balance, polarography, electronic automatic control, paramagnetic resonance, nuclear magnetic resonance, emission spectrum, ultraviolet and visible absorption spectrum, infrared spectrum, joint dispersion spectrum, X-ray, electron diffraction, neutron diffraction, electron microscope, mass spectrograph, isotope marking technique, high energy radiation, and modern methods and equipment, etc. The expansion of research tools and conditions will enable us to effectively produce new synthetics and carefully and closely study the properties, structure and reaction characteristics of inorganic matters; these studies will be enough to improve our understanding about the theory and enough to promote better foundation for better utilization.

4. Since our country is a great country with rich resources, mineral deposits are scattered everywhere; therefore, great industrial development will be established at many areas in the future; in order to satisfy this future trend, many inorganic research centers with first-rate experimental equipment should be set-up at many places. Every center will have its outstanding special topic for study. Each one should try to reach advanced standing in the international circle, and its ability should enable it to solve significant problems encountered in the development of our national economy. Several research centers will be grouped together to form the nucleus of a research network, their work and planning will be greatly coordinated. Of course, the development of inorganic chemistry should be under the overall planning for all branches of chemistry.

To serve the socialist construction of our motherland enthusiastically is the most dignified task as well as the greatest luck of we scientific workers. Inorganic chemists should stand together with scientific workers of other branches of chemistry and other sciences and be under the great leadership of the Chinese Communist Party to develop the highest degree of positive attitude and mobility and to bravely march forward.

## II. CHINA'S PROGRESS IN ORGANIC CHEMISTRY IN RECENT DECADE

Pages 6-8

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The progress of organic chemistry in the decade since the Liberation, as with other branches of science, has been unprecedented because of the unerring leadership of the Party. Before the Liberation, the foundation of China's organic chemistry and other industries was very poor. All research work in organic chemistry was performed in connection with the needs of medical fields (such as Chinese drugs, alkaloids, and hormones) and light industries (such as dyestuffs chemistry, and fiber chemistry); most of the work was toward the direction of the synthesis of complicated natural compounds and their derivatives. Therefore, the accomplishments in spatial chemistry in the field of theoretical organic chemistry were the most noted. Because of the attention and support given to this branch of science by the Party, the research and industrial progress of China's organic chemistry has not only been leaping forward but also has had qualitative changes. Most of all is the change that occurred in the thinking of our research workers. Their projects which have been closely connected with the tasks of our national construction have made a great contribution.

During the period of the past two decades, the development of organic chemistry has been mainly in the following four areas: basic organic chemistry, the chemistry of high-molecule compound, the chemistry of complicated natural compounds (such as alkaloids, vitamins, hormone, and antibiotics) and the chemistry of elementary organic compounds. Since the Liberation, all four fields have been probed.

### A. Research on Heavy Organic Synthesis

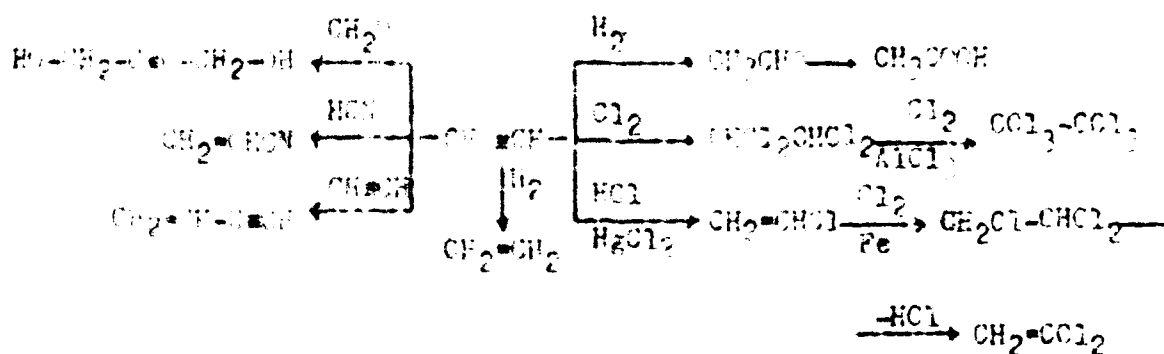
Neither research work nor industries of heavy organic synthesis were established prior to the Liberation in China. But after the Liberation, due to practical production demand by such industries as synthetic rubber, fiber, and plastic, many urgent tasks which were awaiting immediate action were presented to our organic chemistry workers. Because of the attention given by the Party and the assistance rendered by the Soviet Union and many other brotherly countries, work on heavy organic synthesis was soon quickly developed in many research institutes and higher educational facilities. Their growth has been tremendous.

The major problem in heavy organic synthesis is to obtain the synthetic method of principal raw materials and auxiliary materials needed in the preparation of high molecular compounds (such as simple substance, solvent, plasticizer, etc.). The major point is to use cheap and easily obtainable raw materials (such as ethine, natural gas, industrial gases, petroleum, by-products of coal finishing process, by-products of agriculture, air and water) to make important compounds.

## 1. Heavy Organic Synthetic Compounds from Fishine

The study of heavy organic synthetic compounds from ethine didn't start until after the Liberation; a series of projects have been performed in the past decade, the most important are:

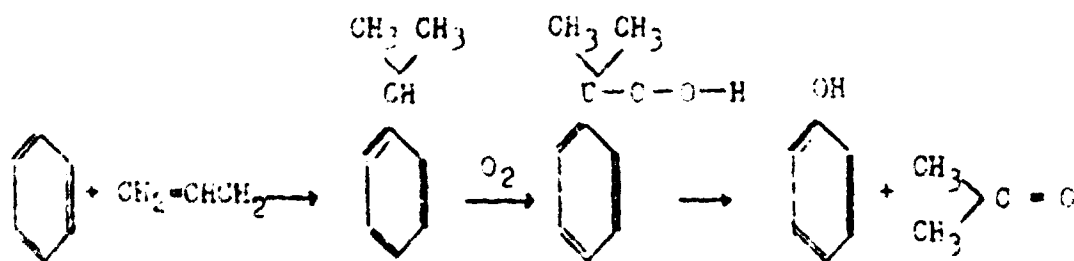
- (1) The preparation of acetaldehyde and acetone by adding water to ethine, and the preparation of acetic acid and acetic anhydride by oxidizing acetaldehyde.
- (2) The preparation of ethyl chloride and vinyl chloride as a simple plastic substance by adding chlorine and hydrogen chloride to ethine.
- (3) The preparation of vinyl acetate as a simple substance of polyvinyl plastic by adding acetic acid to ethine.
- (4) To add formaldehyde to ethine for the preparation of some chemical compounds such as simple substance of artificial plasma and synthetic plastics.
- (5) The synthesis of other products of ethine, such as ethylene, methyl cyanide, and propylene.
- (6) Ethanol is the product of bi-polymerization of acetylene, a further synthesis gives a simple substance of chloroprene rubber. Some of the above mentioned projects are still in the laboratory stage, but some of them have been put into production already. The major reactions are shown below:



## 2. The Utilization of Products from Coal Treatment

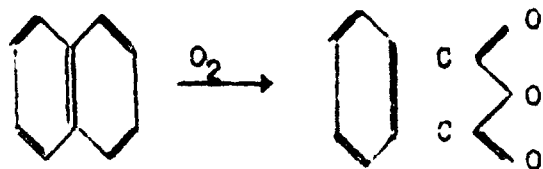
The application of the aromatic compounds, such as benzene, phenol, and naphthalene from coal tar fractional distillation process prior to the liberation was limited to the small-quantity use by pharmaceutical, dyestuff, and plastic (Bakelite) industries, but these compounds have become raw materials for some heavy organic synthetic processes since that time.

The study of heavy organic synthesis from benzene and phenol: In the past, the synthesis of phenol from benzene was made by means of benzene sulphonic acid or chlorobenzene, and to obtain acetone from propylene, the latter had to be hydrated first to become propyl alcohol and then have hydrogen removed by means of catalysis process to get acetone. Recently we have succeeded in using oxidation of isopropyl benzene to obtain phenol and acetone.



Furthermore, we have also studied the synthesis of nylon-6 simple substance from benzene or phenol.

Production has been started on phthalic anhydride by the method of catalytic oxidation of naphthalene. Phthalic anhydride is the important raw material for plastic, paint, pigment, and dyestuff industries.



We also studied the process directly using coarse naphthalene as the raw material, which not only maintained the activity of the catalyst, but also increased the rate of yield of phthalic anhydride. In addition, the ethereal salts of phthalic acid were also studied.



Anthraquinone, which is an important intermediate for dye production, has been produced by boiling-layer catalytic oxidation of anthracene. The process for the preparation of plastic by removing hydrogen from acenaphthene has also been studied.

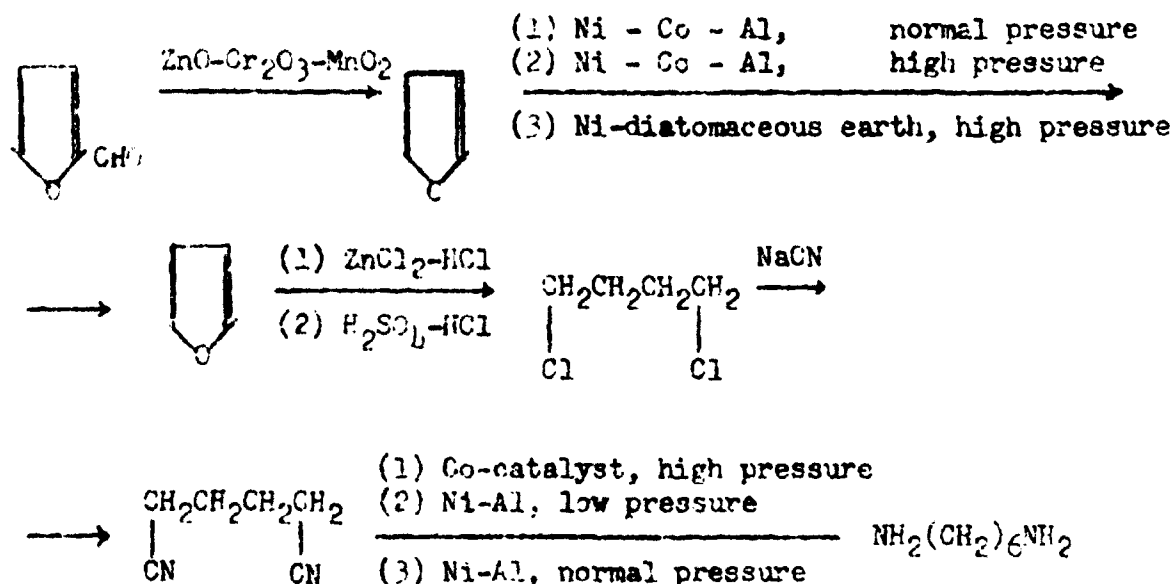
### 3. The Utilization of Agricultural By-Products.

Prior to the Liberation, the application of furfural in our country was limited to minor usages, little was done about the research on the extraction methods of furfural, and there was no application of it in the field of heavy organic chemistry.

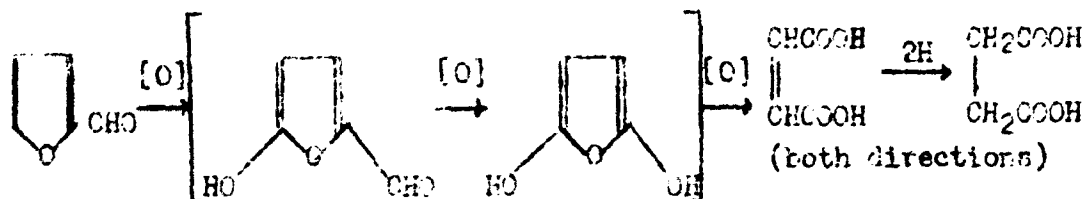
Since the Liberation, especially during the period of the great forward leap, the methods of extraction, preparation, and application of furfural as a raw material for the manufacture of nylon have been studied everywhere.

The heavy organic synthesis with furfural is mainly for the preparation of butane dicarboxylic acid and di-amines as the raw materials for the production of nylon-66. The following two methods have been tried:

(1) The preparation of furan and its derivatives by removing carbonyl from furfural. Furan and its derivatives are the raw materials for nylon-66:



(2) The preparation of succinic anhydride from the oxidation and reduction products of furfural:



The resource of castor oil in China is very rich; it had been used before the Liberation to prepare octyl alcohol and methyl hexyl ketone by the process of saponification cracking and to prepare heptaldehyde, heptyl alcohol and other products through hot cracking process; however, no application was adopted from these cracking products. Since the liberation, the use of castor oil as a raw material for nylon has attracted attention everywhere; especially during the period of the great forward leap, many research and production units have studied the preparation of nylon-9 and nylon-11.

Satisfactory results have also been achieved on the preparation of acetic acid and its derivatives from distillation or fermentation of agricultural by-products, the preparation of oxalic acid from sawdust, and the preparation of acetone by fermentation of farm products.

#### 4. The Utilization of Petroleum and Shale Oil.

Heavy organic chemistry of petroleum and shale oil didn't start until recent years; the main projects include dehydrogenization of low alkanes, the extraction and oxidation of paraffin wax to form high-grade fatty acid and alcohol, and the application of petroleum olefines.

##### (1) De-hydrogenization of low grade alkanes.

Ethylene-butane and butane-butene gas mixtures are obtained by cracking ethane on nickel catalyst, dehydrogenization on chromium oxide-aluminum oxide-potassium oxide catalysts yields butadiene.

##### (2) The application and extraction of paraffin wax.

After the Liberation, a kind of high-wax-content natural asphaltum from which ozokerite can be extracted was found in our country, the ozokerite can be made into various kinds of products such as vaseline after purification. Medium scale experiments have been performed to prepare acetic acid by paraffin wax oxidation.

### (3) The utilization of petroleum olefines.

Alcohols can be made by hydrolysis of low-boiling distillation fraction of petroleum, the polymerization reaction starting from ethylene propylene have also been studied. Olefins ( $\text{RCH}=\text{CH}_2$ ) from shale oil can be used to prepare detergent ( $\text{R-CHMe-OSO}_3\text{Na}$ ).

### 5. The Utilization of Natural Gas.

China has very rich natural gas resources. Recently survey work was carried out by a group of scientists. Most of the activities on the utilization of natural gas as raw material for organic synthesis have been concentrated in recent years on the following projects: (a) the oxidation of marsh gas to form formaldehyde; (b) chlorination of marsh gas to form methyl chloride; (c) formation of organic compounds containing fluorine from synthesis of marsh gas; and (d) the preparation of ethine by hot cracking marsh gas.

### 6. Application of Water Gas and Carbon Dioxide

Prior to the Liberation, no work was done on the organic synthesis using water gas. After the Liberation, because of the synthesis of petroleum work, initial study was carried out on that subject in the period from 1950 to 1952, and some experiences were collected on the synthesis of water gas. Later on, by the use of catalysts from steel smelting, the yield rate was greatly improved and the results are much higher than the results from similar type research published by other literature.

The synthesis of carbonyl chloride from carbon monoxide and air has been under large-scale experimentation. As for the synthesis of heavy organic compounds from carbon dioxide, only urea was studied in this country. The use of catalysts in heavy organic synthesis has greatly improved the reaction rates; in those reactions such as oxidation, de-hydrogenation, hydrogenation, additive reactions, hydrolysis, and alkyl compounds, we not only use catalysts, but also probe the theories behind them.

### B. The Study of Natural Organic Compounds and Pharmaceutical Chemistry

China has vast land and rich resources. Natural organic compounds, therefore, are plentiful. Prior to the Liberation, people were working aimlessly, disorderly, and unrealistically. Since the Liberation, people have clearly learned that the aim of research is for production, and theory should be tied in with practicality. Based on these principles, the research progress of pharmaceutical chemistry and natural organic compounds in a short period of time has solved many practical problems.

The problems confronted in the production of antibiotics, such as penicillin, aureomycin, chloromycetin, and streptomycin were solved shortly after the Liberation, and actual production got underway. Preparatory work has also been started on new antibiotic products. In addition, in order to serve the pasturage industry, work on the development of veterinary antibiotics has been conducted on a widespread basis.

In the preparation of hormones, we have prepared in a very short period more than ten kinds of important hormones which are vital to the health of mankind, such as yellow ketones, etc., and others have already been put into production. The preparation of Ko-Ti-sung is now under large scale experimentation.

The improvement over the direction of development and methods of production of vegetable alkaloid and other vegetable products started gradually after the Liberation. For instance, the study of pharmaceutical plants or vegetables used to be started whenever crystal form could be extracted, no attention was given to the effects of such a study; but now emphasis has been given to the possible separation of the effective constituents of such items, and further study will depend upon this analysis. Furthermore, chemists in the past didn't want to be bothered by the types and origins of various plants which they were using, therefore, frequently it was not possible to repeat and prove an experiment because of the use of wrong plants; this discrepancy has now been eliminated by the cooperation among chemists and botanists who handle identification work.

Many modern methods including ion exchange, color analysis, infra red ray spectrometry, ultraviolet ray spectrometry, etc., have been adopted to study the separation and structure of the constituents of natural resources. The problems studied are much more advanced and the quality of the results has been much improved. So far many different types of vegetable alkaloids such as Tien-chieh, Ma-huang, and Pang-chi have been started with industrial production.

Some work has been systematically done on the study of the chemistry of turpentine products. Many types of perfumes and benzine have had an effect on our productive construction.

Under the direction and organization of the Party, those who practice medicine, who are engaged in medical theory research, and chemists jointly studied antibilharzial drugs and prepared more than 1,000 drugs in a short period of three years. In recent years, their force has been largely shifted to the study of diseases such as high blood pressure and cancer, where effective drugs are lacking.

### C. Element Organic Chemistry Research

Element organic chemistry is an advanced science in the field of organic chemistry. The research situation in countries all over the world is rather impressive, and many accomplishments have been obtained. However, this branch of science was again a blank in China prior to the Liberation. Since then, research work has been concentrated on solving some practical and theoretical problems.

In the field of metal organic compounds, several hundreds of organic compounds of antimony have been prepared during the past ten years for the purpose of finding some effective drugs to combat bilharzial disease. Since the Liberation, agricultural insecticides have been rapidly developed and many effective phosphorous insecticides are now being prepared. In the meantime, some work has also been done on the structure of phosphorous organic compounds and their toxic properties. We also studied mercury organic compounds which can be used as insecticides, magnesium organic testing materials, and organic compounds of tin.

In order to produce insulation materials which can stand a high temperature, organic chemists have studied in the past few years silicon organic compounds and silicon para compounds.

Fluorine organic compounds research has been carried out in other countries for a long time, but it is a weak link in China. Shortly after the Liberation, some scattered work was done on this subject, but during the past couple of years, especially since the year of the great forward leap, the development of fluorine organic compounds and fluorine para-compounds has been rapid.

The significant accomplishments of our organic chemistry stem from the leadership of the Party, the unselfish assistance given by the Soviet Union and other brotherly countries, and the vigor of our organic chemists. During the past decade, our great and eminent party has not only led the political and economic activities in China, but has also correctly led scientific work. In the early stage after the Liberation, scientific workers were directed to tie in science with production and practicality so that research can serve production in a more efficient way. Following the initial stage of development, coordination and planning emerge as the most important tasks. In 1956, the first planning and regulations for science in China's history were drawn up, proper coordination among related research units was organized, and appropriate cooperation and division of work were established among the Academy of Sciences, higher educational facilities, production units, and local organisations. In the meantime, research work has been systematically

carried out according to plan. After the rectification campaign, scientific workers criticized and overcame individualism, gave up what used to be the unrealistic college-style research, positively devoted themselves to socialist construction activity, and happily shouldered those tasks that are more closely connected with production. All these facts contribute to the unprecedented progress and qualitative improvement in the field of organic synthesis.

### III. CHINA'S PROGRESS IN PHYSICAL CHEMISTRY IN RECENT DECADE

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#### Introduction

Prior to the Liberation, scientific research in old China received no one's attention; furthermore, since China's agricultural and industrial production levels were very poor, the development of scientific research was impractical. This is also true for physical chemistry which is a branch of chemistry. At that time, only a few physical chemists did some scattered and unsystematical research work, almost all of which was done in foreign countries. Since equipment was scarce in China, the establishment of any research center was out of the question. Teaching of physical chemistry in colleges and universities was comparatively out of date, therefore, very few physical chemists were trained through these organizations.

Since the Liberation, scientific research work has been given the most serious consideration by the Party. Under the correct leadership of the Party's scientific development policy, scientific research work is booming in this country. The high speed development of the production level of agriculture, industry and other branches in our socialist construction program has been challenging the domain of physical chemistry with many urgent problems pending immediate solutions. Of course, these demands have promoted and accelerated the research work of physical chemistry. During the past decade, the noted accomplishments in the field of physical chemistry include high molecule chemistry, chemical kinetics, structure of matter, electrochemistry, colloid chemistry and the theory of solution; definite progress has been made in these vital fields. Furthermore, all work is arranged systematically and is objective. It generally begins with tackling a practical problem and gradually moves to a theoretical study. Quantitatively, the work has exceeded the sum of what had been done before the Liberation; and the quality of present work is beyond any comparison with the past. Furthermore, modern methods and equipment used in present research have guaranteed better results. Up to now, better physical chemistry laboratories have been established in various research facilities and higher educational organizations all over the country, and many research centers established at various important areas of the country have shown satisfactory results. A large number of devoted workers are being trained in various higher educational facilities and scientific research

organizations and they are the decisive factor in the future continuous development of our physical chemistry. In order to achieve this goal, the colleges and universities in China are now trying hard to improve the teaching of physical chemistry.

Of course, looking at the needs of the Party and the people and the requirements of industry, agriculture and other branches needed to carry out their development, the present accomplishments in our field fall far short, and some defects in the development of a better connection between theoretical study and practical application and in the effective training of a large number of red and expert scientists should be eliminated.

The following report covers the accomplishments in the various fields of physical chemistry during the past decade; since the domain of physical chemistry is so broad, work outside of the following topics but related to physical chemistry will be introduced under related headings.

### Structure of Matter

There are two divisions of this subject. One is the theory of chemical bond and the other is the development of structure chemistry.

The theory of chemical bond studies the property and behavior of the binding force of atoms; at the present time, we are using the theory of the movement and distribution of electrons to explain the binding inside molecules as well as the atomic binding between molecules, this is also connected with the properties of molecules. The study of chemical bond theory in China started during the early stage of the Liberation, work was more on the theory of irregular orbit and the theory of internal molecular spin. Later on, following the growth of our research forces, the theory of molecular orbit, the theory of multiple electron bond function, and inter-molecular applying force study were added.

The following are the achievements in the study of molecular structure and chemical bond function. We have suggested the method to work out the best bond function and the matrix method of bond function so that the development of irregular orbit theory on the subjects of the discussion of bond strength, bond angle, and bond property and of the derivation of bond function can be further probed. The calculation method for multi-electron bond function suggested by us is important in the future development of molecule structure theory. Cylindrical free electron model has satisfactorily explained the absorption spectrum of starch-iodides; the use of molecular orbit method to treat AB<sub>2</sub> type inorganic molecules such as NO<sub>2</sub> and SO<sub>2</sub> explains the chemical



bond problem of these molecules. As for the study of property and molecular structure, our work has been more or less concentrated on the problem of internal molecular spin. We have achieved important results on the potential function of internal spin and the computation of the terminal distance and average radius of high molecules. We have also carried out meaningful analysis and computation for the optical activity of cyclo-pentanone, bond energy of alkanes, and ionization constants of oxy-acids. On the subject of the inter-molecular applying force, we use our own  $1/r_{12}$  double-center spherical-coordinate equation to carry out over-all quantum mechanic treatment of Van der Waal's force. We also carried out a new computation for the binding energy of hydrogen bond. In the study of atomic structure and property, we have probed the problems concerning the negative electrical potential of the atom, its magnetic susceptibility, and the energy levels of electrons inside an atom.

In structure chemistry, we organize and collect all data concerning the structures of compounds on the one hand; on the other, we draw from these data conclusions on the possible forms and features of combinations by various elements in various chemical compounds, the relationship between chemical formation and the types of bonds and structure, and the connection between bond and structure types and various properties. Since it takes considerable time to establish experimental conditions in the study of structure chemistry, our actual work started gradually in 1954; but by 1957, our achievements in the study of crystal structure of alloy, inorganic and organic compounds have been numerous.

In the study of alloy crystal and its phase change rule, one example is that in ternary systems, such as the Al-Cu-Ni system, we have found a series of interesting superstructures for  $\beta$  phase and further studied the factors governing the change of structure. We have studied in detail the ordered-disordered inversion of (Au, Ag)Zn alloy. In inorganic compounds, the structure of  $Sb_2S_5$  and  $P_4S_3$  sulfides of the nitrogen family were studied. In addition, we studied the properties of the double reaction surrounded sulfuric acid, sodium bisulfite additive products of acrolein, and the crystal structure of 2-sodium 3-biselenite. From the study of the structure of anhydrous sodium sulfite, we revealed the disordered distribution of atoms and the process to realize such disordering. During the past, the structure of  $Ca_2Al_2Si_3O_{10}(OH)_2$  was never quite understood; not until recently did we obtain a new silicon-oxygen structure. The crystal structure of  $Ni(CH_3CHNH_2COO)_2 \cdot 4H_2O$  is a hydrogen-bond system made of hydrated water and a two-water molecule. The crystal structure of the intermediate product of benzonitrile from Stephen reaction has been determined.

In the study of the spectrum, except for the satisfactory results obtained when the absorption spectrum in the ultra-violet region was seen in starch-iodine compound, the combined scattering spectrum of benzoic acid solution was studied. We also investigated the electrical moment of couple of hydroxy silane and para methyl methacrylate; the results indicate that the measurement of electrical moment of couple is helpful to the study of internal spin of molecules and of the short range structure of high molecule chain.

### Chemical Kinetics

The principle task of chemical kinetics research is to study the rate of chemical reactions, the effects of various factors on reaction rate, and the processes of various types of chemical reactions. To control these conditions means the control of reaction rates and to eliminate non-essential secondary reactions; therefore, the reaction may follow the pre-set course.

Prior to the Liberation, little knowledge had been accumulated on this study, except for a few chemists who did some works in foreign countries; in China no work was done. Since the Liberation, the development of science under the Party's leadership has been tremendous. The development of industry, especially the development of our petroleum industry, has stimulated the study of chemical kinetics in certain fields. During the past decade, the development of our chemical research can be divided into the following three areas, namely, homogeneous kinetics, high-molecule reaction kinetics, and heterogeneous catalytic kinetics.

The accomplishments in the study of homogeneous kinetics include the detailed reaction process of a new kind of hydrogen catalysis from the esterification of simple acids and simple alcohols. From this discovery, the kinetic equations for such reactions under different conditions may be recorded and the degree of esterification reaction under such conditions may also be determined; this accomplishment has cleared the long time argument on the mechanism and degree of esterification process. In addition, we studied the effect of negative amino substitute on the hydrolysis rate of 2-amino-2-dehydroxy-D-corn sugar. Experimental results support the theory of Neuberger and others. As for the theory of aqueous saponification of ethyl acetate in the mixture of low-constituent diethylene oxide and water, experimental results disagree with the theory of Moelwyn-Hughes, Laidler-Eyring, and Amis-Jaffe. The study of the thermal-analysis of isopropyl benzene and hydrogen peroxide has shown us that its thermal decomposition in isopropyl benzene is not a pure first rate reaction; this shows that the oxidation reaction of methyl methacrylate belongs to ionization type chain reaction. The rate of cementation of silica gel has proved

that its mechanisms in acid and in alkali are different; the photochemical reaction and oxidation of  $\text{SO}_2$  in atmosphere in industrial areas were studied; we also found the activation energy of the reactions between olefines and  $\text{CCl}_4$ ,  $\text{HCCl}_3$ ,  $\text{SiCl}_4$ , and  $\text{HSiCl}_3$ . We also studied the kinetics of combination between o-toluidine and p-nitrosophenol and the Men-shu-teh-chin reaction.

*Monashuthin*  
High molecule chemistry is the branch of science developed very rapidly in recent years, its research has very important practical as well as theoretical significance. Since the Liberation, some accomplishments have been made in the study of kinetics of polyaddition and polycondensation reactions in the physical chemistry side of high molecule chemistry. Polyaddition action of high molecule is a chain reaction which can be divided into free type and ion type; generally the treatment of kinetic data for both types are based on the stable state theory of Bodenstein; we have carried out very careful mathematical analysis of the kinetics of polyaddition and found that Bodenstein's theory is applicable to free base type polyaddition reaction. We also studied the competition rate of polymerization of methyl methacrylate, butyl propionate, cenanthic ether, and vinyl acetate. On the subject of polycondensation reaction kinetics of high molecule, almost the entire theoretical field was examined, we pointed out that the molecular weight distribution of polycondensation products in the presence of dissociative reaction follows Flory's theory, and we also discussed the problem of gelatinization during the process of polycondensation. We have suggested the hydrogen ion catalytic mechanism in the process of poly-esterification of binary acids and binary alcohols; the kinetic equation for the polyesterification of simple acids and alcohols was proposed and verified by experiments. We have confirmed the triple-direction polyesterification reactions of poly-basic acids and alcohols also belong to hydrogen-ion catalytic mechanism. By investigating the relationship between molecular structure and reaction rate constants for binary acids and alcohols, we confirmed a basic hypothesis concerning the reaction kinetics of polycondensation, but for which there was a lack of experimental proof. All these results have made a definite contribution to the study of the theory of high-molecule polycondensation. In addition, the condensation kinetics of dimethyl-diethylene-silane was studied.

In this country the research on heterogeneous kinetics started from the catalytic finishing research on the catalytic processes of sulfuric acid, the synthesis of  $\text{NH}_3$ , petroleum olefines, and the synthesis of water gas. The following work on basic concepts and theoretical presentation has been performed. First of all, in the study of catalytic kinetics of petroleum olefines, we used the material balance relationship to bring the reaction rate concept of a static

system to a dynamic system, by doing so, we have reasonably solved a basic problem in heterogeneous kinetics. We have given detailed analysis of the Frost kinetic equation which is often used in catalytic cracking to find out conditions under which this equation bears the clear meaning of kinetics. The effects of chromium catalyst on the aromatization of heptane and the laws govern the kinetic theory of aromatization, one of the special examples is the law of the sedimentation of carbon. The theories of Steiner, Plote, and Kagan about the dehydrogenation of heptane still exist; from the preliminary discussion of reaction mechanism, we may admit that the Kagan theory about semi-hydrogenated mechanism is appropriate. To supply the kinetic data for the design of an industrial reactor, we studied the effects of the reaction conditions of  $K_2O-Cr_2O_3-Al_2O_3$  catalyst on the rate of aromatization and carbon sedimentation of the 7-carbon distillation fraction of synthetic gasoline. In the use of catalyst rectification to produce aromatic hydrocarbons from petroleum, we have the control of the newest platinum method; we have studied in detail the mutual relationship among the reactions and the principle kinetics theory governing the treatment of pure hydrocarbons by this method. In addition, we have worked on  $MoS_2$  catalyst, hydrogenation of benzene and the kinetics of isomeric chemistry. In the field of inorganic catalytic kinetics, a kinetic equation has been obtained for  $SO_2$  oxidation of vanadium catalyst when the effects of mass transfer process is eliminated and the activity of the catalyst is independent of the different ways to reach a reaction condition. This indicates that the effects of the mass transfer process under different catalyst granular conditions and different temperatures upon the reaction rate are obvious. We also studied the kinetics of the oxidation of  $SO_2$  on vanadium catalyst with promoters containing potassium and sodium; from these results, we worked out an approximate kinetic equation for industrial vanadium catalysts. The inverse relationship between internal surface utilization percentage and the conversion ratio of Tung-ii vanadium catalyst was obtained from computation. By using the industrial chlorinated pulp process, we studied the reaction rate and properties of chlorine and wood in the process of gas-solid contact operation.

### Electrochemistry -- The Theory of Solution

The major task of electrochemistry is to study the chemical reactions conditions and rules which initiate by electrical energy (electrolysis) and to convert chemical energy into electrical energy (chemical source of electrical energy). Such conversion is through the use of electrolytic solution (or melted salt). Some of the work on electrolytic solution will be introduced later in the section concerning the theory of solution. The most special features of modern electrochemistry are the development of the electrode process theory

and the wide application of electrochemistry. Electrode process represents the chemical change that occurs at the contact surface between electrode and electrolyte when the mutual conversion between chemical and electrical energies takes place. These electrochemical processes are vital to the national economy. Since the electrolysis method is widely used in chemical, metallurgical, electro-plating, and metal polishing processes, the chemical electrical source following the wave of high speed development of various scientific and industrial technologies is getting more important everyday. The methods used in electrochemical analysis are being widely used in analytical chemistry.

Prior to the Liberation, electrochemical industry in old China was extremely backward, which naturally shut down the door for its research activity. After the Liberation and following the high speed development of our socialist construction, the old electrochemical industry was expanded and a new type electrochemical industry has emerged. The speedy development of the chemical-electrical energy industry started in the initial stage of the great forward leap. Such progress has presented electrochemistry with increasing demand. Under the correct leadership of the Party's science development policy, electrochemists first studied the practical problems vital to the development of our national economy; following the progress of industries, practical tasks started to challenge theoretical development with a series of urgent problems pending immediate solutions; this was where research work on electrode process theory started. Although the work was begun not long ago, accomplishments are significant.

We have been successful in the study of the mechanisms which are responsible for the formation of oxygen on the positive platinum electrode and the formation of  $S_2O_8^{2-}$  at the positive electrode. Both electrode processes are very important to industry. To the former mechanism, we have proved the mechanism in dilute  $H_2SO_4$  at low current density, suggested the oxygen formation mechanism at high current density, and carried out theoretical analysis of the oxygen formation in concentrated sulfuric acid. For the latter case, we have for the first time successfully separated from the total polarization curve two independent polarisation curves belonging to the  $O_2$  positive electrode formation and the  $S_2O_8^{2-}$  positive electrode formation; we have proved that the formation mechanism of  $S_2O_8^{2-}$  is due to direct electrical discharge of  $HSO_4^-$  or  $SO_4^{2-}$  ions. Based on this proof, we further studied and explained theoretically the cause that industrial use additive ions such as  $F^-$  and  $CNS^-$  raise the electrical current efficiency of  $S_2O_8^{2-}$  formation. We also have made some accomplishments in the method of deriving the determinative steps in the "deduction" of the electrode process. In addition, a conclusion on the positive-electrode oxidation mechanism of benzyl alcohol in sulfuric acid

solution has been worked out. The double-layer capacitance of the antimony electrode was measured by the alternate current method; and the zero-charge potential of antimony was also measured for the first time.

Since the Liberation, and following the large production rate of steel and nonferrous metals and the development of mechanical and chemical industries, metal corrosion and anti-corrosion have become extremely important problems. To study the electrode process of corrosive metal often points out the causes for the corrosion, the factors which control the corrosion rate, and the mechanism and effects of the agencies which slow down the rate of corrosion. The use of the electrochemical method to combat corrosion is often one of the most effective approaches to this problem. We have studied the reasons for phosphates as the anti-corrosives for manganese steel. In order to study the anti-corrosion properties of antimony plating, we have determined the anti-corrosion properties of antimony in various electrolytes. The corrosive action of sodium benzoate and triethyl alcohol benzoate upon steel was studied and shown. We have pointed out the corrosive mechanism of  $\text{Ag}^+$ ,  $\text{Cu}^{++}$ ,  $\text{Fe}^{+++}$ ,  $\text{Ce}^{++++}$ , and halogen ions on 18-8 stainless steel.

On the subject of electrochemical instrumentation study, we have simplified Heyrovsky's polarographic oscillographic circuit. A simpler equivalent circuit gives the same shape as the original circuit, and an oscillator is used to study the voltage-current relationship. On the theory of oscillographic polarography, we used experiments to verify the Randles-Sevcik equation and pointed out the discrepancy between the theory and the experimental results. For the theory of anode polarography, we have pointed out the mistakes in the reverse polarographical current equation proposed by Hickling in 1956. In addition, we also studied some other electrochemical analysis methods; we proposed a "polarographical titration instrument" using an electronic circuit which can be used in oxidation and reduction processes. The theory of the double-electrode indicative electrode current titration method was given detailed quantitative discussion.

In metal plating, the first thing we did was to use elements found abundant in this country to replace scarce metals in metal plating. We have studied the polarization phenomenon of electrical accumulation of antimony and the conditions necessary for better antimony plating; we also found a better base solution for antimony plating. We have carried out a detailed study about the conditions for cobalt-wolfram alloy; under proper conditions, cobalt-wolfram alloy containing wolfram up to 54.2% can be electrically plated. To find a substitute for nickel, we have successfully found the conditions for bronze plating.

On the subject of electrolytic preparation of chemical materials and metal electrical refining processes, we have tried a series of new methods for the preparation of alkalis and chlorine with electrolytic processes. We designed and studied the electrolytic bath and conditions of electrolysis of  $\text{KClO}_3$  and the technical process of electrolytic preparation of  $\text{KMnO}_4$  was studied. The preparation of wild-pear alcohol and mannitol and the electrolytic reduction process for corn sugar were also studied. On the subject of electrolysis of fused salts, the effect of adding  $\text{MgF}_2$  and  $\text{NaCl}$  to an aluminum electrolytic bath was investigated. Many rare metals have been prepared with the fused salt electrolytic method.

The foundation of the chemical electrical source industry inherited from old China was extremely poor; there were only two sequences producing less than ten items, the techniques used were manual and backward. After the Liberation, due to the rapid development and urgent demand of various industrial branches, communication tools, as well as new scientific techniques, the chemical electrical source industry under the leadership of the Party was greatly developed; the initial research was mainly on the technology side, scientific research has already been started with limited activities and future development is urgently needed.

The major development of the chemical electrical power supply was concentrated on the improvement over the quality of old products and at the same time increasing new items. For instance, the life span of the lead battery has been increased from 200 in 1956 to 300 in 1958. Due to improvement on corrosion of zinc plate, the discharging period of the zinc-manganese dry battery has been increased from 400 minutes to 580 minutes. Other new sequences, such as the preparation and production of alkali nickel steel and nickel-cadmium batteries, have also been added. In addition, we are also studying new and high-energy batteries, the preparation or production of silver-zinc batteries, zinc-mercury dry batteries, zinc-carbon alkali batteries, and iron-carbon batteries.

A fuel battery which is more efficient than fire electrical power is now under study.

Prior to the Liberation, research on the theory of solution was also extremely poor; some people did scattered work. Since the Liberation, new development has been given to this branch of science. The study of solution theory bears very practical significance to the chemical industry.

On the subject of phase equilibrium of poly element systems, we have constructed the phase diagram for the ethyl alcohol-nitro benzene-water and the ethyl alcohol-furfural-water ternary system; we also

measured the critical-point constituents of the systems. From the study of the distribution coefficients for l-ephedrine and mixed ephedrine in toluene, xylol, and chloro-benzene and water, we have found the most appropriate conditions to extract ephedrine with the continuous solvent extraction method. On gas-liquid equilibrium, a new simpler method to calculate ternary system equilibrium data from binary system for heptane-toluene-phenol system was obtained. We have probed theoretically the conditions for the establishment of the van Laar equation with temperature. On instrumentation, we have designed a very simple gas-liquid equilibrium probe whose accuracy can be compared with more complicated instruments.

We based the study of salt solution from the structure point on the Samoylov theory; the solubility of  $\text{NaHCO}_3\text{-KHCO}_3\text{-H}_2\text{O}$ ,  $\text{KSCN-KI-H}_2\text{O}$ , and  $\text{KCl-K}_2\text{SO}_4\text{-H}_2\text{O}$  was studied, these results have helped to explain the structure of salt solutions. By the use of the conductivity and electrical potential measured from the water solution of sodium salt of undecylic acid, we are sure that there is no association phenomenon in the undecylic acid radical. Furthermore, we have conducted an overall measurement of conductivity of naphthyl-amine hydrochloride, N-methyl aniline, and N-ethylaniline in water and diethylene oxide mixed solution.

In a study of salt effects from the research on the effects of larger cations and anions on the solubility in water of non-electrolytic naphthalene, normal valeric acid and normal caproic acid molecules, we pointed out that the van der Waals-London dispersion action theory may give definite explanation of the salt effect of salt with comparatively larger ions on non-polarized molecules (naphthalene); however, for organic acids, replacement chemical reactions and post-reaction distribution should be considered first.

Furthermore, from much experimental data, we have concluded the study on salt solution temperature coefficients, salt structure, and the empirical rule on the directional relationship of crystal water and ionic valence, and obtained the empirical rules for the determination of the strength of inorganic oxy-acids and their molecular structures. Furthermore, we also calculated the hydrolysis of acid salts formed from the reaction of strong alkalies and weak acids and discussed the domain of application of common ion effect equation.

### Colloid Chemistry

There is no real clear division about this branch of chemistry, it is a rather broad science. Here we will only discuss things related to traditional colloid chemistry and successful applications of colloid chemistry which have brought satisfactory solutions to those problems.



On the subject of surface tension and absorption research, theoretical calculation and empirical equations about surface tension for many liquids and liquid metals have been worked out separately. On the subject of gas absorption, a series of studies concerning the absorption of steam of  $N_2$ ,  $CO_2$ ,  $CH_3OH$  and hexa-carbon hydrocarbons by silica gel of different size porous was carried out; molecular absorption state and the absorption potential of different silica gels were analyzed. To coordinate the research on catalytic cracking, the absorption of alkali nitrogen compounds on catalysts was measured; from these results, we believed that besides acid centers, there are also polarization centers on the surface of catalysts. On auto-solution absorption, we studied surface tension and absorption of the fat ammonia water solution. The study of mixed acid solution absorption has revealed that the surface absorption of sugar carbon is not a simple substitution mechanism. The study of absorption thermodynamics has given us the simplest method for a solution to absorb free energy and proved that the rules govern the absorption in solution by solids may also be used on liquid surface absorption. We also studied the mechanism of absorbing ammonium salts by soil.

Catalytic phenomenon has a close relationship with surface chemistry; therefore, the study of the surface properties of catalysts is important to the better understanding of catalytic reactions. Our work has been concentrated on the study of the activity center of cracking catalysts from poisoning phenomenon and absorption properties and of the surface effects when the constituents of catalysts are changed. From this work we have obtained our preliminary conclusion about the properties of the catalyst surface activity center.

Another important section of surface chemistry is ion exchange. Based on the special features of the soils of our land, our soil experts have studied ion exchange of the soils, established several methods to measure the quantity of ion exchange, studied the soil acidity-ion exchange relationship, and ion absorption equilibrium; various physical chemistry methods have been used to analyze the soil structure.

Greater achievements have been obtained from our liquid and gaseous spectrum study. Most of the work and most of the accomplishments have been in the analysis and separation of petroleum, shale oil, gas tar and in a high speed analytical method and separation method for accurate determination of the complicated composition of some oils. Especially in the field of gaseous spectrum research, we have not only improved operational techniques but also separated systems which still cannot be done in foreign countries; in the field of theoretical study, we have made some fundamental contributions and have further explained the physical significance of the qualitative index of the volumetric

gas spectrum. Starting with the separation of two different materials, we have reached the index equation for the thermal spectrum column effect which has been further expanded to the gas-liquid spectrum. The unbalanced theory was also studied.

For the colloidization of silicic acid, an over-all study on the polymerization mechanism of different acidity silicic acids and the relationship between the colloidization rate and pH have been completed; the curves plotted on the logarithm of colloidization time vs. the solution initial pH are N-shape curves with a maximum and minimum. Besides, we also studied the effects of preparation conditions for silica gel on humidity absorption.

On the subject of colloid stability, we measured the poly-precipitation values of some metal ions upon negative AgBr colloidal solution; based on these experimental results, we also analyzed the effects of ion valance and ion radius on those values. Some work was done on the stability of the non-hydrogel soap oil system; from factors such as temperature, pressure, gelatinization contraction rate, titration, needle reading, stored oil fraction, cutting stability, viscosity, and soap percentage, we carried out research work with different approaches on the stability of grease (soap oil system) and the results obtained have practical and theoretical significance.

In the newly developed field of rheology, we have carried out a study on the relationship between viscosity and constituents of binary solutions, and the flow pattern of aluminum soap (binary and ternary) benzene solution. We also carried out a broad and deep penetrating study of the viscosity method for high polymer molecular weight determination. The rheological properties such as viscosity of solid high polymers were also investigated. The rheological property of sand in water, which is closely related to water conservation work, was not extensively studied. Some measurements concerning the viscosity and precipitating rate of sand-mud were taken and calculated. The part of soil mechanics which is related to colloid chemistry was studied. We designed a torsion plasticity meter to study the post-transformation process of rich soil, and also analyzed theoretically the structure of soils and the mutual relationship among material points.

In conclusion, the accomplishments during the past decade have qualitatively and quantitatively surpassed the total work done during several decades prior to the Liberation. Looking at the needs of our country, the research work on colloid chemistry in the past ten years was certainly insufficient, this is especially true for traditional colloid chemistry and the colloidal system. In the future, effort should be given to the development of this research work.